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EXPLOSIVE COMPARISON TRIALS; CAST TNT AND TNT DRILL DUST

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Interim Report, October 2005

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14. ABSTRACT
A series of six blast experiments was conducted to compare the blast environments produced by Cast TNT (military TNT Demolition Charge blocks) and by TNT Drill Dust, a by-product of reclaiming cast TNT from decommissioned military ordnance. Each experiment employed 50-lb net explosive weight of the test explosive, and the blast environment was compared with that predicted by the ConWep software tool for uncased TNT. The Cast TNT produced a blast environment more energetic than predicted for TNT, resulting in a recommended 1.10 TNT-equivalent weight. The TNT Drill Dust produced a blast environment less energetic than predicted for TNT, resulting in a recommended 0.90 TNT-equivalent weight. Both explosives produced stable, and hence predictable, blast environments, and are suitable for use in blast effects research.

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This report is published in the interest of scientific and technical information exchange and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

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1. EXECUTIVE SUMMARY

A series of six blast experiments was conducted to compare the blast environments produced by Cast TNT (military TNT Demolition Charge blocks) and by TNT Drill Dust, a by-product of reclaiming cast TNT from decommissioned military ordnance. Each experiment employed 50-lb net explosive weight of the test explosive, and the blast environment was compared with that predicted by the ConWep software tool for uncased TNT. The Cast TNT produced a blast environment more energetic than predicted for TNT, resulting in a recommended 1.10 TNT-equivalent weight. The TNT Drill Dust produced a blast environment less energetic than predicted for TNT, resulting in a recommended 0.90 TNT-equivalent weight. Both explosives produced stable, and hence predictable, blast environments, and are suitable for use in blast effects research.

2. INTRODUCTION

2,4,6-trinitrotoluene, or TNT, is an important explosive that provides numerous advantages to ammunition manufacturers and explosive handlers. First, it melts at a reasonably low temperature (81°C or 178°F), allowing it to be melted and poured into shells and bombs (called *cast TNT*). Second, it is sufficiently stable to permit safe handling during manufacture and operations. TNT can, in fact, be handled fairly roughly, generally requiring the pressure wave from another less stable explosive to initiate detonation. TNT is considered the “standard” explosive, against which other high explosives are typically compared in terms of explosive energy and overpressure effects. This comparison is usually expressed in terms of TNT-equivalent weight, defined as the number of pounds TNT required to produce the blast effects produced by 1-lb of explosive.

As military ordnance is decommissioned as excess or unserviceable, the explosive materials are often reclaimed. A by-product of reclaiming cast TNT from ordnance is a material called *TNT Drill Dust.* While TNT is normally a light yellow material, drill dust is a slightly darker yellow, powdery material. And also unlike pure TNT, drill dust is somewhat hydroscopic, tending to cake and clump as it is exposed to atmospheric humidity.

Because it is a reclaimed product, TNT drill dust offers cost advantages over pure TNT for blast effect experiments. As such, the Air Force Research Laboratory (AFRL) at Tyndall Air Force Base, Florida was interested in determining the suitability of TNT drill dust in AFRL research efforts to understand explosive effects on structures. An experiment was conducted at Tyndall’s Test Range II on 1 December 2004 to compare the blast environment produced by TNT drill dust with that produced by cast TNT.

3. EXPERIMENTAL PROCEDURE

3.1 Technical Approach. A series of six (6) trials was conducted on 1 December 2004, three trials using 50 pounds of cast TNT blocks, and three trials using 50 pounds of TNT drill dust. Data collection included pressure-time histories, high-speed video to record fireball dimensions, and residue sampling. The residue sampling results are not included herein and will be reported under a separate report.

3.2 TNT Configurations. The 50-lbs cast TNT test articles were made up using 50 each standard military 1-pound TNT Demo Charge blocks (cast TNT), stood on end in a closely-packed 5 x 10 array. The TNT drill dust test articles were comprised of 50 pound bags of TNT drill dust, configured to closely replicate the size and shape of the cast TNT blocks. All charges were elevated 3.28 feet (1 meter) above the ground, and detonated using an RP-83 Exploding Bridge Wire Detonator (Figure 1).

Cast TNT **TNT Drill Dust**

Figure 1. TNT Configurations

3.2 Pressure Instrumentation. The pressure-time histories were obtained using eight AFRL saucer-shaped incident pressure gauges (containing Kulite XT-190 pressure gauges), located in all four primary compass directions at distances of 30 and 42 feet from the center of the test articles (Figure 2). Note that the instrumentation stands located close to ground zero in Figure 2 are residue sample collectors, and are not included in this technical report.

Incident Pressure Gauge

Blast Arena Setup

Figure 2. Pressure Gauge Layout

4. RESULTS

4.1 Pressure-Time Histories. Table 1 summarizes the results of the pressure-time history analyses. Predictions for time of arrival of the pressure wave, peak incident pressure and peak impulse were made using the ConWep software tool using uncased TNT in a hemispherical surface burst. The test results represent the averages from all eight gauges and all three replicates for each TNT configuration (cast TNT and TNT drill dust).

Table 1. Average Pressure-Time Histories

Test Article	Time of Arrival	Pressure	Impulse
ConWep Prediction			
50 lbs TNT @ 30 ft	11.42 ms	14.38 psi	35.68 psi-ms
50 lbs TNT @ 42 ft	19.95 ms	7.49 psi	26.59 psi-ms
Cast TNT			
50 lbs TNT @ 30 ft	11.93 ms	15.08 psi	35.98 psi-ms
50 lbs TNT @ 42 ft	20.09 ms	8.49 psi	28.32 psi-ms
TNT Drill Dust			
50 lbs TNT @ 30 ft	12.96 ms	12.58 psi	31.98 psi-ms
50 lbs TNT @ 42 ft	21.46 ms	7.58 psi	25.13 psi-ms

Figures 3 and 4 graph the pressure-time histories for a typical cast TNT shot and a typical TNT drill dust shot, respectively. Figure 5 graphically plots the results of each pressure measurement, and Figure 6 plots the impulse data. The Appendix includes the detailed data and pressure-time plots.

4.2 Fireball Diameter. The diameter of the fireball was scaled graphically using the high-speed video taken of each shot, captured at the moment of maximum fireball extent. Table 2 summarizes the results of these measurements, and Figure 7 is a typical screen capture showing how the fireball was measured. The known distance between the outermost pressure gauges was used as a scale for fireball measurements.

Table 2. Measured Fireball Diameter Results

TEST	FIREBALL DIAMETER
Cast1	35 ft
Cast2	35 ft
Cast3	39 ft
Average of Cast TNT	**36.3 ft**
Dust1	39 ft
Dust2	35 ft
Dust3	38 ft
Average of TNT Drill Dust	**37.3 ft**

5. DISCUSSION

5.1 Data Quality. A review of Figures 3 and 4, along with the plots contained in the Appendix, show that the pressure data was relatively consistent in all directions and for all gauges. Furthermore, the plotted results in Figures 5 and 6 show good data clustering, with the possible exception of the 30-foot range for the third cast TNT test (Cast3). Overall, the data appears to be of high quality and reliable.

5.2 Pressure Analysis. A study of Figure 5 shows that the cast TNT tended to produce pressures that were approximately 5 to 13% greater than predicted, whereas the TNT drill dust generated pressures that were between 12% below to 1% above the ConWep prediction. The drill dust shows a definite trend to produce lower pressures than the cast TNT, as might be expected when one considers that the product is likely somewhat contaminated during manufacture (Paragraph 2). Despite this contamination, the drill dust produced results that were at least as stable as those of the pure cast TNT product.

5.3 Impulse Analysis. A study of Figure 6 shows that the cast TNT also tended to produce slightly higher impulses than the TNT drill dust, consistent with the findings of pressure. The cast TNT exceeded the predicted value by 1 to 6%, whereas the TNT drill dust was 6 to 10% below predictions. As was noted for pressure, the impulse data for both products was relatively stable, suggesting that either explosive could be used to produce a good quality, predictable blast environment.

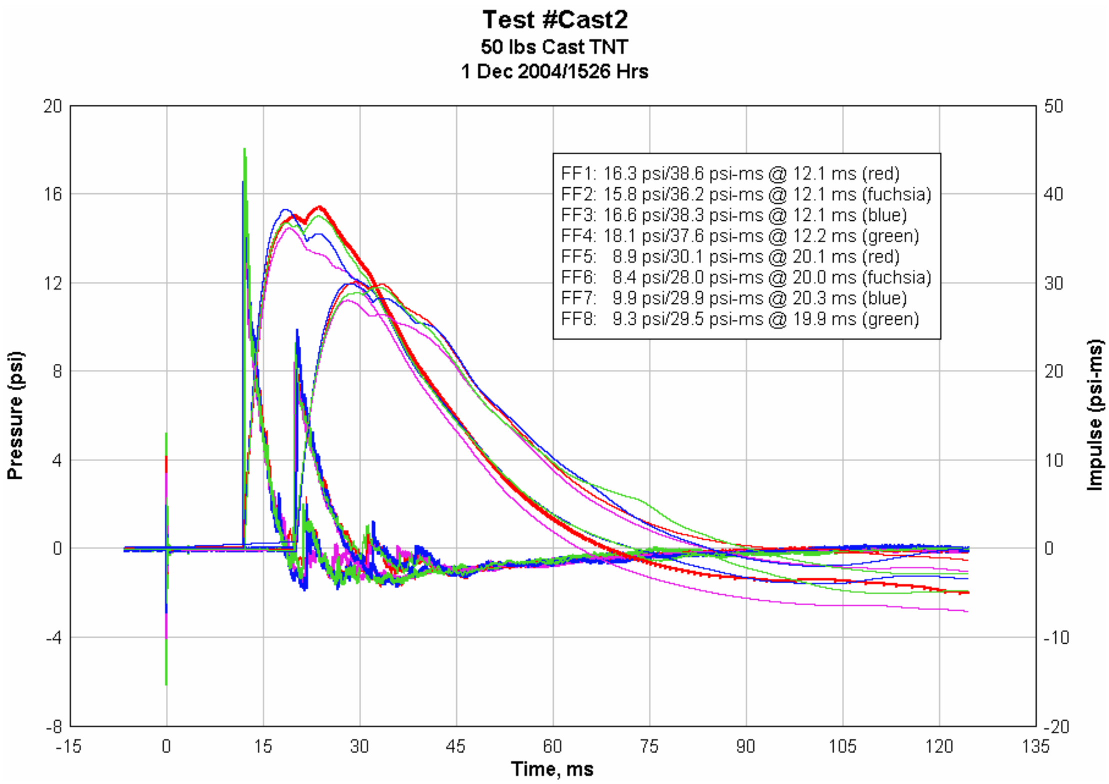


Figure 3. Typical Cast TNT Pressure-Time History

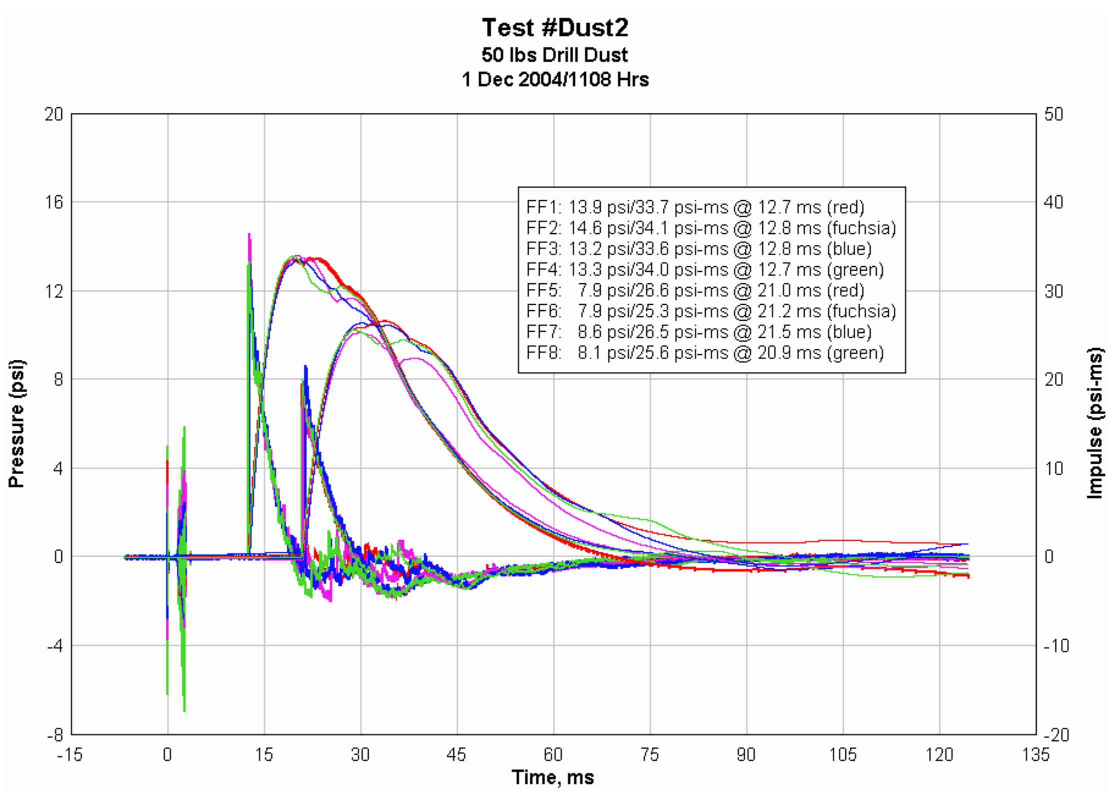


Figure 4. Typical TNT Drill Dust Pressure-Time History

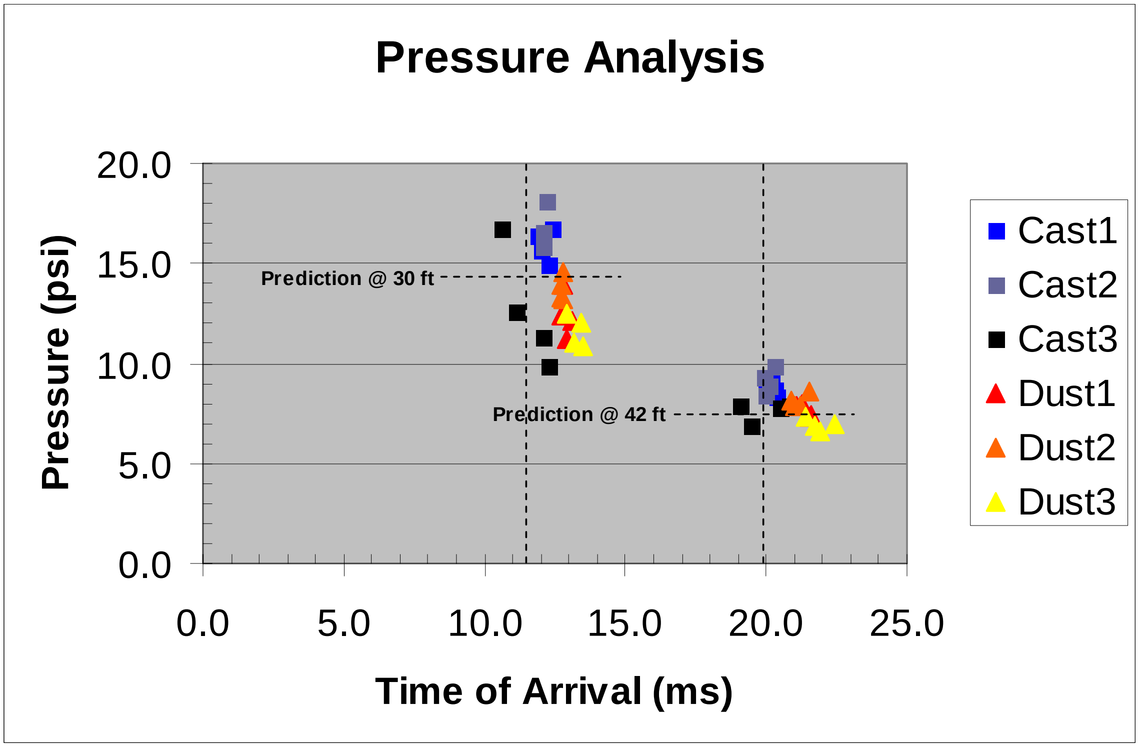


Figure 5. Plot of Pressure Data

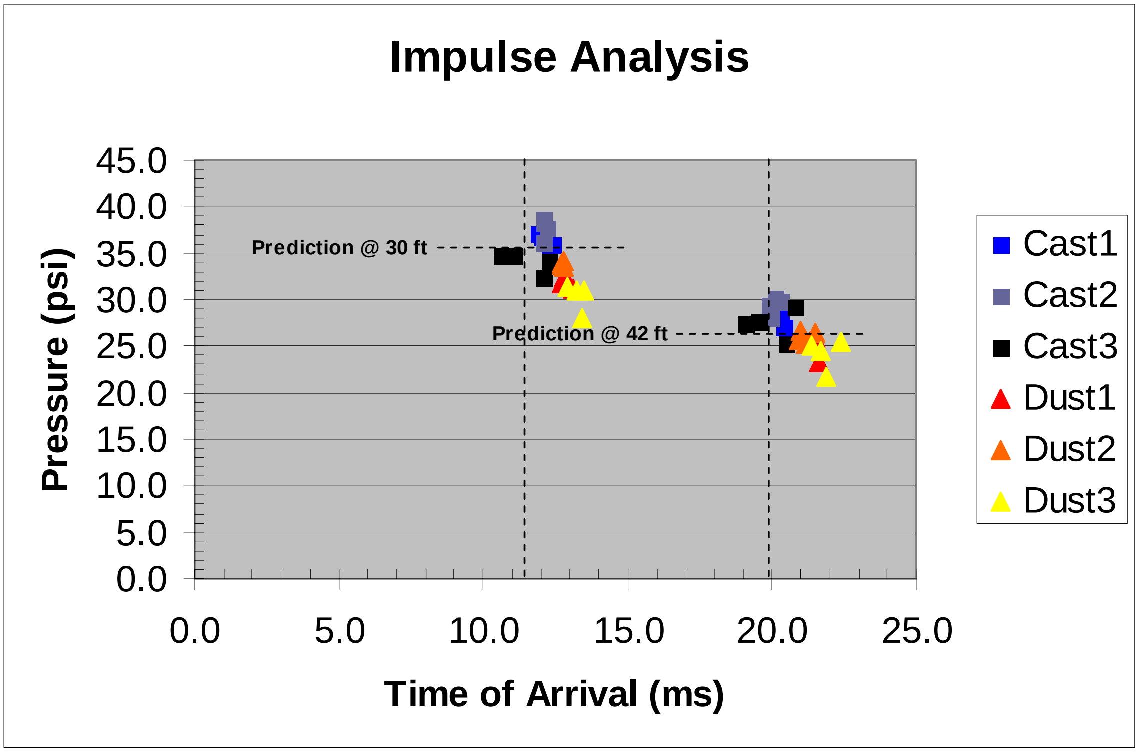


Figure 6. Plot of Impulse Data

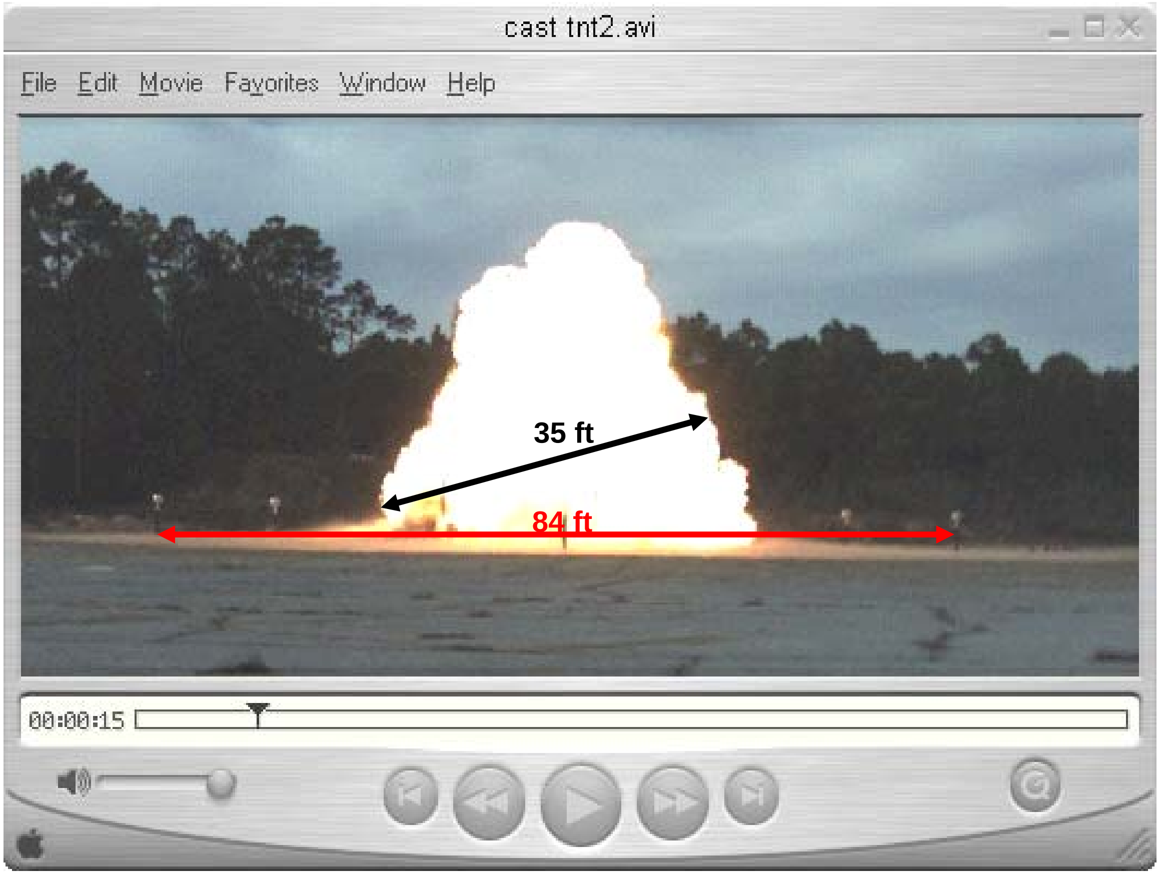


Figure 7. Typical Fireball Diameter Measurement

5.4 Equivalent Weight of TNT. For estimating the performance of explosive shots using cast TNT or TNT drill dust, the concept of equivalent TNT weight is convenient. The character of the blast wave from all high explosives is remarkably similar, permitting the use of common prediction curves by calculating an equivalent charge weight of an explosive required to produce the same blast environment as TNT. Using ConWep, the equivalent TNT weight was calculated from the pressure and range data, as shown in Table 3.

Table 3. Equivalent Weights of TNT

Explosive Weight	Equivalent TNT Weight for Pressure	Ratio for Pressure	Equivalent TNT Weight for Impulse	Ratio for Impulse
50-lbs Cast TNT @ 30 ft	53.6 lbs	1.07	50.7	1.01
50-lbs Cast TNT @ 42 ft	61.3 lbs	1.23	55.3	1.11
Average for Cast TNT		**1.15**		**1.06**
50-lbs TNT Drill Dust @ 30 ft	41.1 lbs	0.82	42.0	0.84
50-lbs TNT Drill Dust @ 42 ft	51.0 lbs	1.02	45.7	0.91
Average for TNT Drill Dust		**0.92**		**0.88**

5.5 Fireball Diameter. In order to further understand similarities/differences between cast TNT and TNT drill dust, the fireball diameters were measured using the graphical approach outlined in Paragraph 4.2. The results are summarized in Table 2. The average diameter was slightly larger for the TNT drill dust test articles. Interestingly, the shapes of the fireballs were also somewhat different, with the cast TNT having a fairly clean, conical shape whereas the TNT drill dust fireball was a less uniform sphere on a sphere (Figure 8). For the purposes of generating an explosive environment for blast effect research, however, these shape differences are likely not significant.

Cast TNT Fireball

TNT Drill Dust Fireball

Figure 8. Comparison of Fireball Shapes

6. CONCLUSIONS

6.1 Based on the results of this experiment, cast TNT produces a blast environment slightly greater than that predicted for TNT. The recommended equivalent weight for cast TNT is 1.15 lbs TNT-equivalent for pressure, and 1.06 lbs TNT-equivalent for impulse. Due to the limited data, use of an average TNT-equivalent of 1.10 lbs for all calculations seems justified.

6.2 Based on the results of this experiment, TNT drill dust produces a blast environment less energetic than that predicted for TNT. The recommended equivalent weight for TNT drill dust is 0.92 lbs TNT-equivalent for pressure, and 0.88 lbs TNT-equivalent for impulse. Due to the limited data, use of an average TNT-equivalent of 0.90 lbs for all calculations seems justified.

6.3 Both cast TNT and TNT drill dust produced relatively stable, and hence predictable, blast environments. The use of either, with appropriate adjustments as discussed in Paragraphs 6.1 and 6.2, is justified for blast effects research.

7. REFERENCES

7.1 ConWep (Conventional Weapons Effects software), Version 2.1.0.8, USAE Engineer Research & Development Center, Vicksburg, MS (For Official Use Only).

7.2 Cooper, Paul W., *Explosives Engineering*, Wiley-VCH, Inc., New York, 1996.

APPENDIX – Data

Explosive Comparison Trials
1-Dec-04

ConWep Predictions	Time of Arrival (ms)	FF Pressure (psi)	Impulse (psi-ms)
50lbs TNT @ 30ft	11.42	14.38	35.68
50lbs TNT @ 42ft	19.95	7.49	26.59

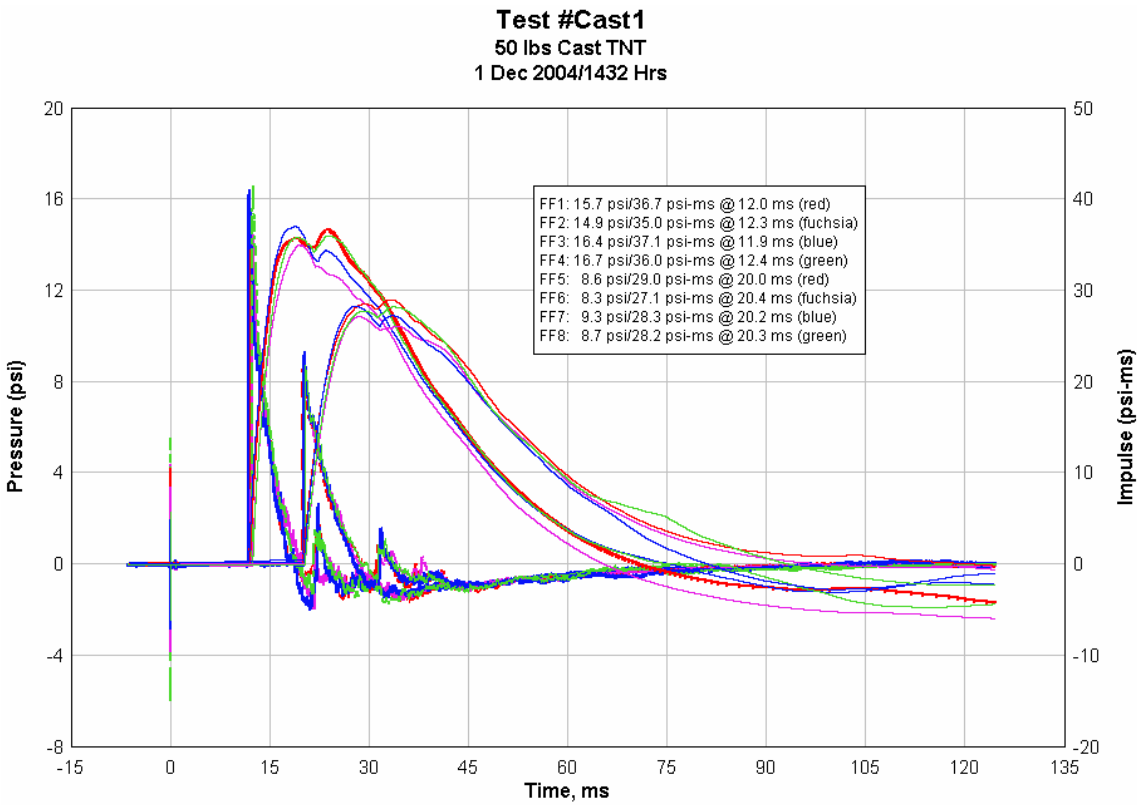
Experimental Results

		Cast1			Cast2			Cast3	
	TOA (ms)	Pres (psi)	I (psi-ms)	TOA (ms)	Pres (psi)	I (psi-ms)	TOA (ms)	Pres (psi)	I (psi-ms)
FF1	12.0	15.7	36.7	12.1	16.3	38.6	11.1	12.6	34.8
FF2	12.3	14.9	35.0	12.1	15.8	36.2	12.1	11.3	32.4
FF3	11.9	16.4	37.1	12.1	16.6	38.3	10.6	16.7	34.8
FF4	12.4	16.7	36.0	12.2	18.1	37.6	12.3	9.9	34.2
FF5	20.0	8.6	29.0	20.1	8.9	30.1	19.5	6.9	27.6
FF6	20.4	8.3	27.1	20.0	8.4	28.0	20.5	7.8	25.3
FF7	20.2	9.3	28.3	20.3	9.9	29.9	19.1	7.9	27.5
FF8	20.3	8.7	28.2	19.9	9.3	29.5	20.8	7.9	29.3
Avg30'	12.15	15.93	36.20	12.13	16.70	37.68	11.53	12.63	34.05
StD30'	0.24	0.80	0.92	0.05	0.99	1.07	0.81	2.93	1.14
Exp/Pred	1.06	1.11	1.01	1.06	1.16	1.06	1.01	0.88	0.95
Avg42'	20.23	8.73	28.15	20.08	9.13	29.38	19.98	7.63	27.43
Std42'	0.17	0.42	0.79	0.17	0.63	0.95	0.81	0.49	1.64
Exp/Pred	1.01	1.16	1.06	1.01	1.22	1.10	1.00	1.02	1.03

ALL CAST	TOA (ms)	Pres (psi)	I (psi-ms)
Avg30'	11.93	15.08	35.98
StD30'	0.53	2.49	1.82
Exp/Pred	1.04	1.05	1.01
Avg42'	20.09	8.49	28.32
Std42'	0.45	0.81	1.36
Exp/Pred	1.01	1.13	1.06

		Dust1			Dust2			Dust3	
	TOA (ms)	Pres (psi)	I (psi-ms)	TOA (ms)	Pres (psi)	I (psi-ms)	TOA (ms)	Pres (psi)	I (psi-ms)
FF1	12.8	13.9	32.3	12.7	13.9	33.7	12.9	12.5	31.4
FF2	13.1	12.1	31.1	12.8	14.6	34.1	13.4	12.0	28
FF3	12.7	12.4	31.7	12.8	13.2	33.6	13.5	10.9	30.9
FF4	12.9	11.2	31.9	12.7	13.3	34.0	13.2	11.0	31
FF5	21.1	7.9	25.9	21.0	7.9	26.6	21.4	7.3	25.1
FF6	21.6	7.4	23.3	21.2	7.9	25.3	21.9	6.6	21.8
FF7	21.5	7.3	25.9	21.5	8.6	26.5	22.4	7.0	25.5
FF8	21.3	8.0	25.5	20.9	8.1	25.6	21.7	6.9	24.5
Avg30'	12.88	12.40	31.75	12.75	13.75	33.85	13.25	11.60	30.33
StD30'	0.17	1.12	0.50	0.06	0.65	0.24	0.26	0.78	1.56
Exp/Pred	1.13	0.86	0.89	1.12	0.96	0.95	1.16	0.81	0.85
Avg42'	21.38	7.65	25.15	21.15	8.13	26.00	21.85	6.95	24.23
Std42'	0.22	0.35	1.25	0.26	0.33	0.65	0.42	0.29	1.67
Exp/Pred	1.07	1.02	0.95	1.06	1.08	0.98	1.10	0.93	0.91

ALL DUST	TOA (ms)	Pres (psi)	I (psi-ms)
Avg30'	12.96	12.58	31.98
StD30'	0.28	1.22	1.74
Exp/Pred	1.13	0.88	0.90
Avg42'	21.46	7.58	25.13
Std42'	0.42	0.58	1.37
Exp/Pred	1.08	1.01	0.94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50 lbs Cast TNT
1 Dec 2004/1432 Hrs
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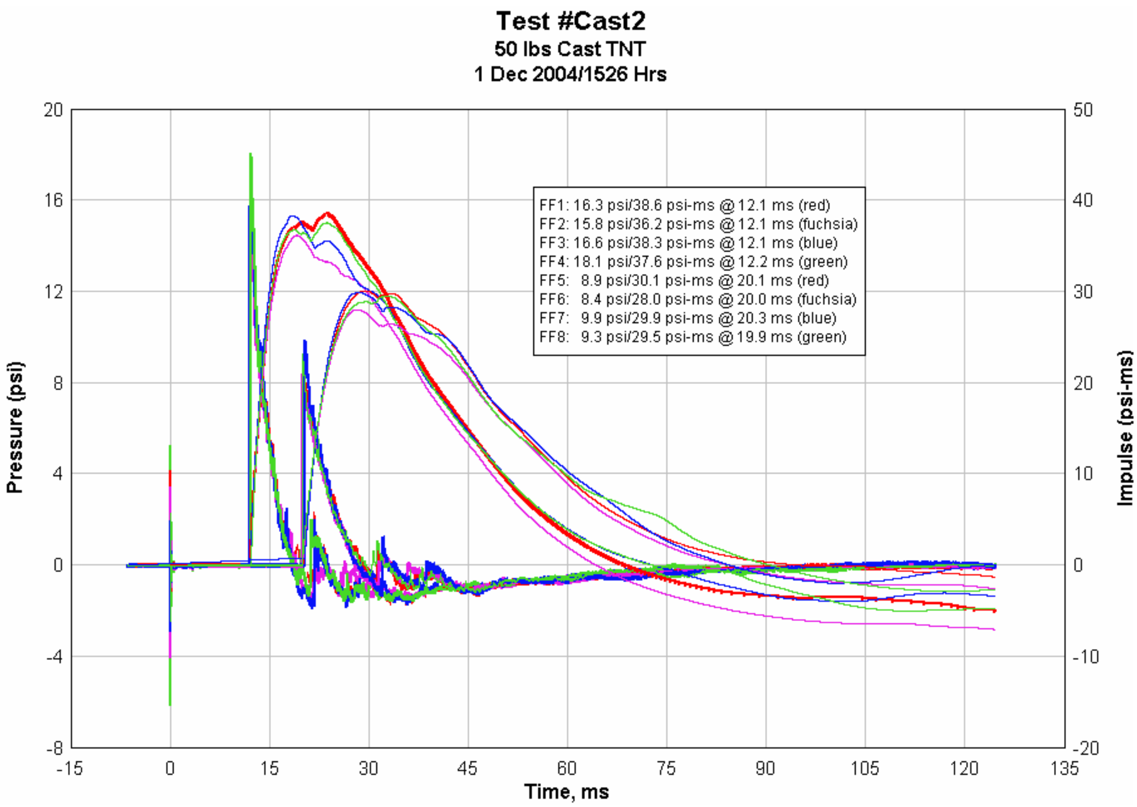
FF2: 14.9 psi/35.0 psi-ms @ 12.3 ms (fuchsia)
FF3: 16.4 psi/37.1 psi-ms @ 11.9 ms (blue)
FF4: 16.7 psi/36.0 psi-ms @ 12.4 ms (green)
FF5: 8.6 psi/29.0 psi-ms @ 20.0 ms (red)
FF6: 8.3 psi/27.1 psi-ms @ 20.4 ms (fuchsia)
FF7: 9.3 psi/28.3 psi-ms @ 20.2 ms (blue)
FF8: 8.7 psi/28.2 psi-ms @ 20.3 ms (green)
Pressure (psi)
Impulse (psi-ms)
Time, ms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50 lbs Cast TNT
1 Dec 2004/1526 Hrs
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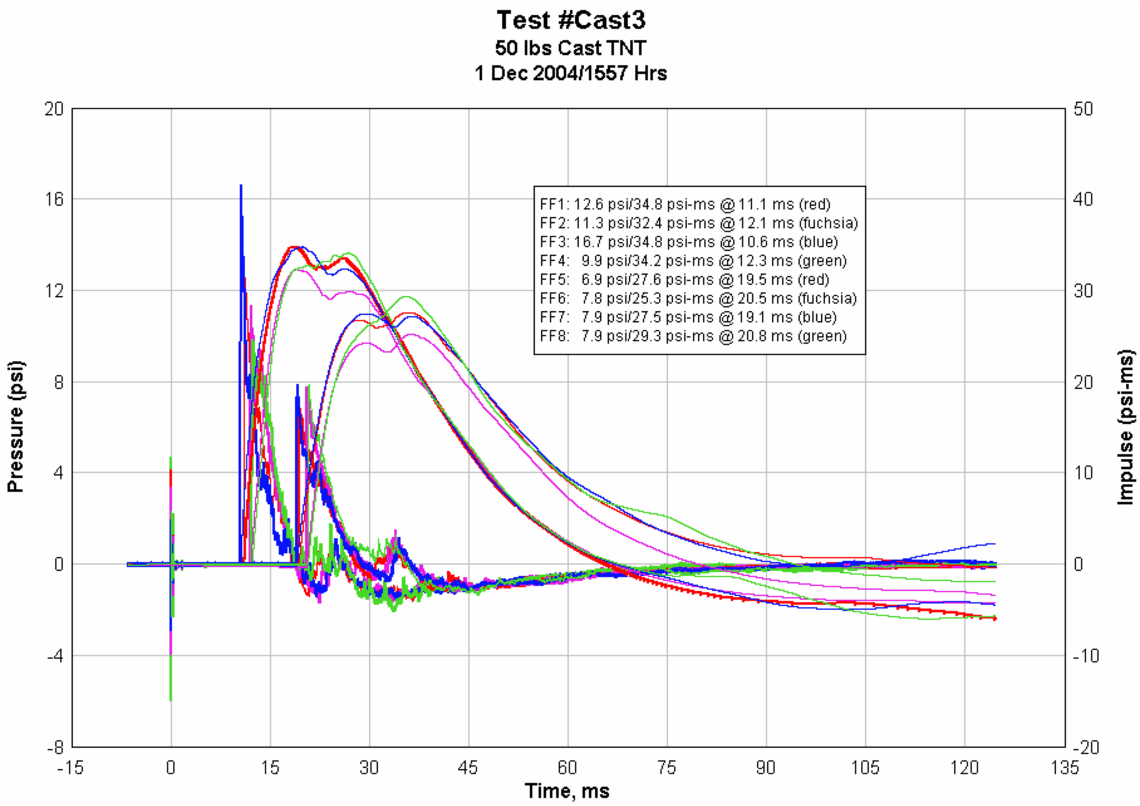
FF3: 16.6 psi/38.3 psi-ms @ 12.1 ms (blue)
FF4: 18.1 psi/37.6 psi-ms @ 12.2 ms (green)
FF5: 8.9 psi/30.1 psi-ms @ 20.1 ms (red)
FF6: 8.4 psi/28.0 psi-ms @ 20.0 ms (fuchsia)
FF7: 9.9 psi/29.9 psi-ms @ 20.3 ms (blue)
FF8: 9.3 psi/29.5 psi-ms @ 19.9 ms (green)
Pressure (psi)
Impulse (psi-ms)
Time, ms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50 lbs Cast TNT
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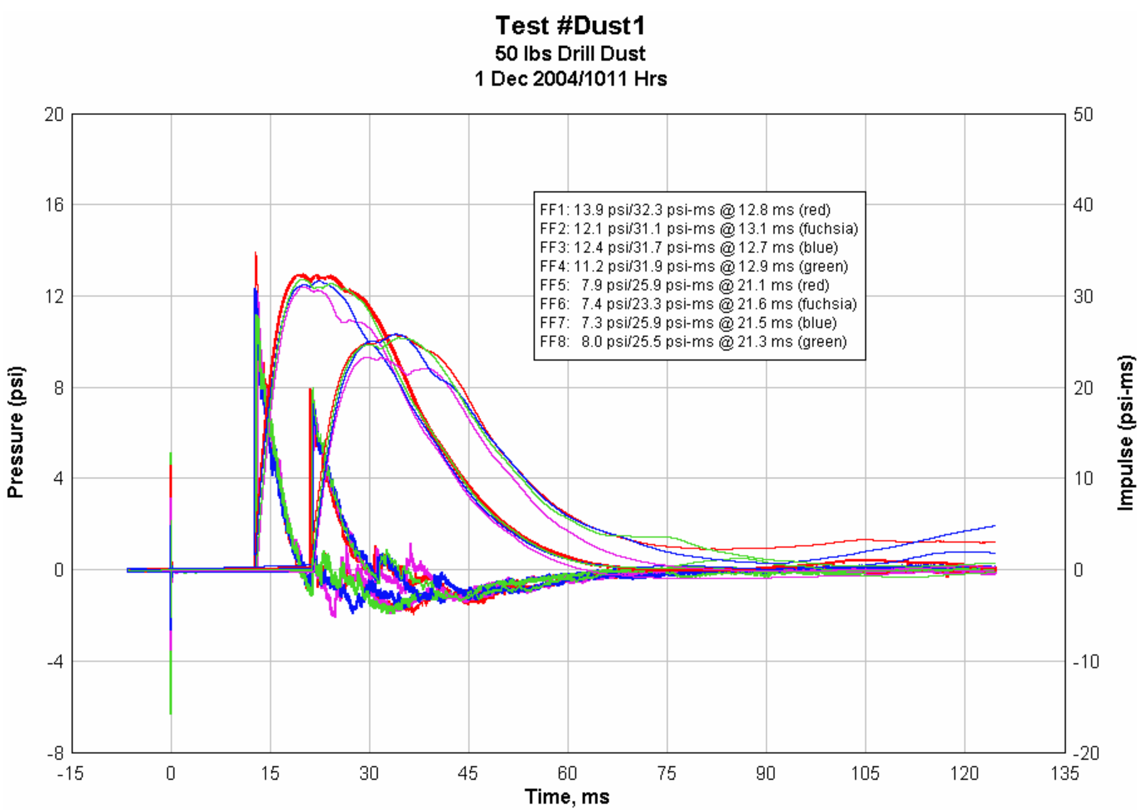
FF3: 16.7 psi/34.8 psi-ms @ 10.6 ms (blue)
FF4: 9.9 psi/34.2 psi-ms @ 12.3 ms (green)
FF5: 6.9 psi/27.6 psi-ms @ 19.5 ms (red)
FF6: 7.8 psi/25.3 psi-ms @ 20.5 ms (fuchsia)
FF7: 7.9 psi/27.5 psi-ms @ 19.1 ms (blue)
FF8: 7.9 psi/29.3 psi-ms @ 20.8 ms (green)
Pressure (psi)
Impulse (psi-ms)
Time, ms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FF4: 11.2 psi/31.9 psi-ms @ 12.9 ms (green)
FF5: 7.9 psi/25.9 psi-ms @ 21.1 ms (red)
FF6: 7.4 psi/23.3 psi-ms @ 21.6 ms (fuchsia)
FF7: 7.3 psi/25.9 psi-ms @ 21.5 ms (blue)
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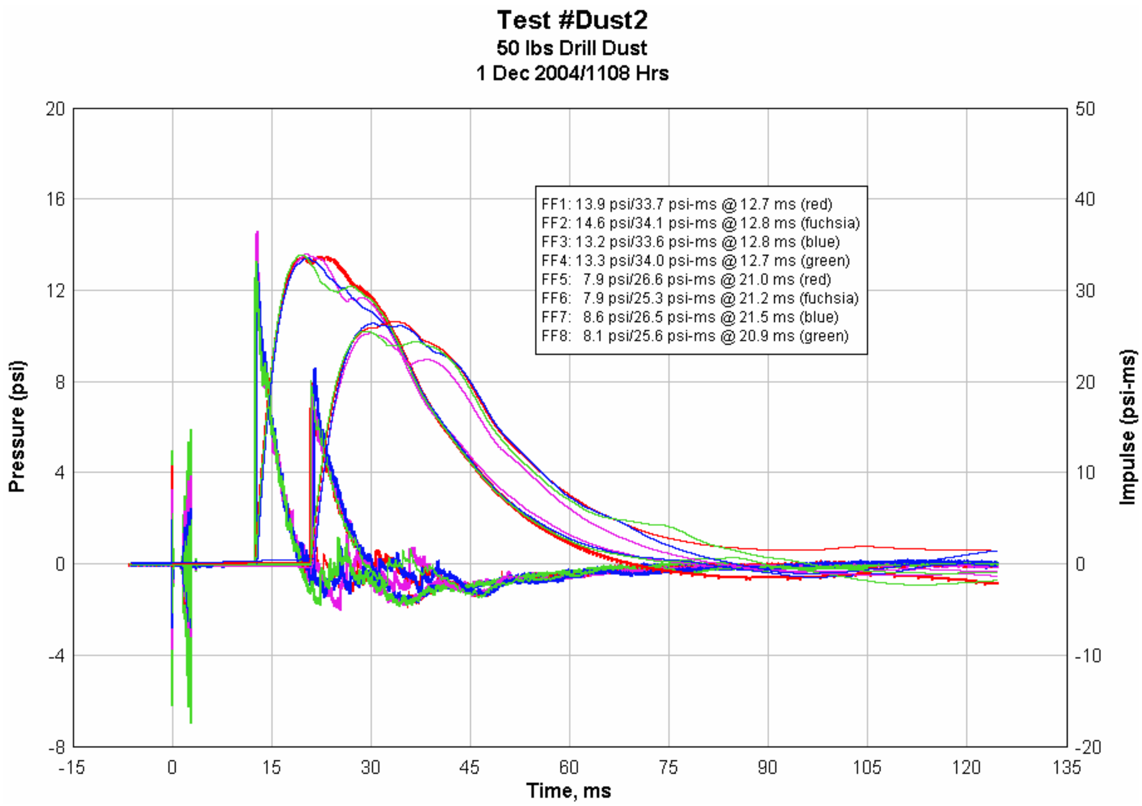
Impulse (psi-ms)
Time, ms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FF4: 13.3 psi/34.0 psi-ms @ 12.7 ms (green)
FF5: 7.9 psi/26.6 psi-ms @ 21.0 ms (red)
FF6: 7.9 psi/25.3 psi-ms @ 21.2 ms (fuchsia)
FF7: 8.6 psi/26.5 psi-ms @ 21.5 ms (blue)
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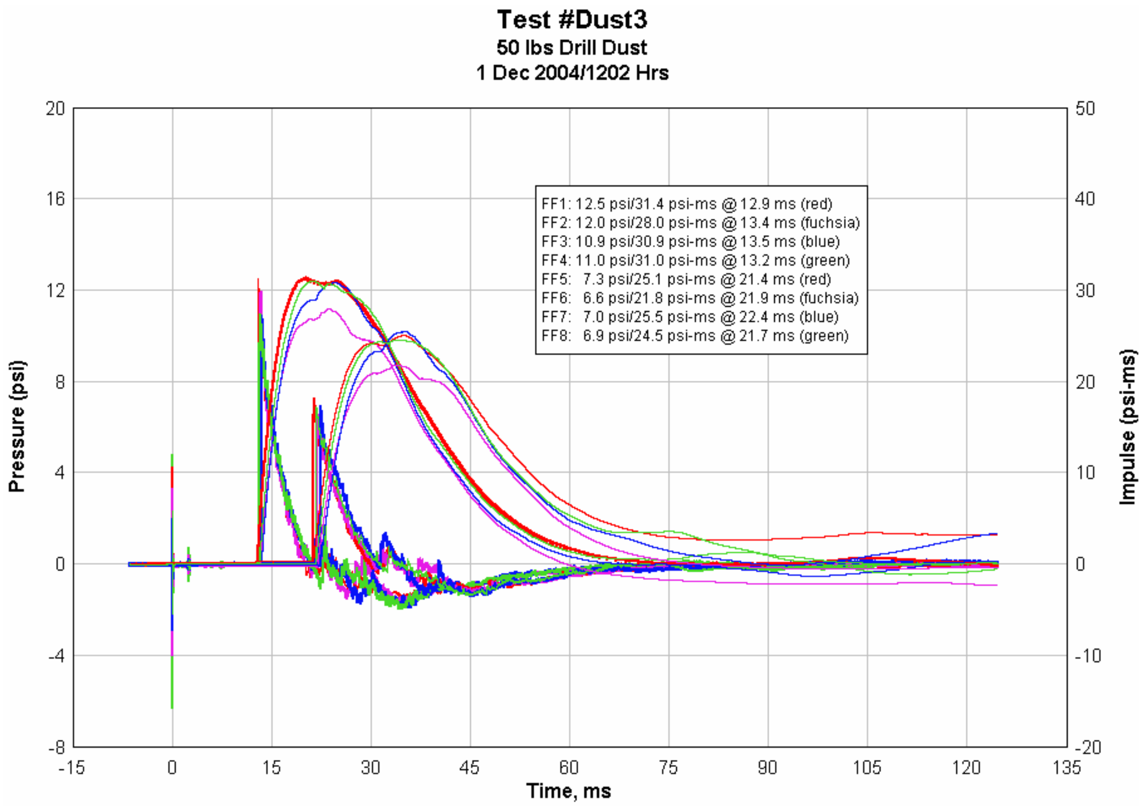
Impulse (psi-ms)
Time, ms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FF3: 10.9 psi/30.9 psi-ms @ 13.5 ms (blue)
FF4: 11.0 psi/31.0 psi-ms @ 13.2 ms (green)
FF5: 7.3 psi/25.1 psi-ms @ 21.4 ms (red)
FF6: 6.6 psi/21.8 psi-ms @ 21.9 ms (fuchsia)
FF7: 7.0 psi/25.5 psi-ms @ 22.4 ms (blue)
FF8: 6.9 psi/24.5 psi-ms @ 21.7 ms (green)
Pressure (psi)
Impulse (psi-ms)
Time, ms